DIVISION OF ENTOMOLOGY

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INTRODUCTION

REPORT OF WORK
OF THE
EXPERIMENT STATION
OF THE
HAWAIIAN SUGAR PLANTERS' ASSOCIATION

Leaf-Hoppers and their Natural Enemies

(INTRODUCTION)

BY R. C. L. PERKINS

HONOLULU, H. T.
MAY 1, 1906

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LETTER OF TRANSMITTAL.

Honolulu, T. H., April 3rd, 1906.

To the Committee on Experiment Station, H. S. P. A., Honolulu, T. H.

Gentlemen:—I herewith submit for publication the Introduction to the Bulletin on "Leaf-Hoppers and Their Natural Enemies," and also an index to this Bulletin. The latter has been prepared by Mr. G. W. Kirkaldy. Although the material dealing with the subject of Leaf-Hoppers is far from being completely worked out, and new material is from time to time being accumulated, yet I have thought it advisable to close Bulletin I, which has now reached a length of more than 500 pages. At the same time, considering the practical and scientific value of such work, I hope that the subject will be continued in another Bulletin.

Yours obediently,

R. C. L. PERKINS,

Director, Division of Entomology.

TO

ALBERT KOEBELE,

THIS RECORD OF HIS RECENT FIELD-WORK,

IS DEDICATED

BY HIS COLLEAGUES,

THE AUTHORS.

GENERAL ACCOUNT OF WORK DONE IN AUSTRALIA, FIJI AND THE UNITED STATES.

The material on which this Bulletin, entitled "Leaf-Hoppers and Their Natural Enemies," is based, has been derived from various localities and sources, which are herewith specified.

(1). In 1903 Mr. Koebele made extensive observations on this subject in North America, chiefly in the states of Ohio and California, and sent a large amount of living material to the Hawaiian Islands.

(2). In 1904 Mr. Koebele accompanied by the writer visited Australia and a still larger collection of leaf-hoppers and their enemies was made in that country.

(3). In the early months of 1905, after I returned to these islands, Mr. Koebele spent a short time in Fiji, continuing Australian studies.

(4). For several years the sugar-cane and some other leaf-hoppers and their enemies have been under close observation in the Hawaiian Islands, and a collection of these has been made.

I will now make some remarks on these various expeditions, showing what was achieved in each case.

KOEBELE'S MISSION TO THE UNITED STATES.

Mr. Koebele's researches in Ohio in 1903 were primarily undertaken on information kindly given him by Dr. L. O. Howard, of the Department of Agriculture. A short time previously Mr. Otto H. Swezey had discovered that certain leaf-hoppers in that State were attacked by Hymenopterous parasites, and Mr. Koebele was notified of this fact by the chief of the entomological staff at Washington. Mr. Koebele's investigations resulted in the discovery of many such parasites, belonging to the family Dryinidae. The appearance of these parasites is well exemplified by the "Fairchild parasite" (*Echthrodelphax fairchildii*) of the cane leaf-hopper, now so familiar to most Hawaiian cane-planters.

In addition to these Dryinidae, the little Mymarid egg-parasite of Liburnia (*Anagrus columbi*) was discovered, and also the common presence of the minute Stylopids of the genus *Elenchus* and others. Finally there was procured a single puparium of a

Dipterous parasite, from which no mature insect was bred, but it unquestionably belonged to a species of *Pipunculus*.

The immediate and actual results of Mr. Koebele's consignments of North American insects were on the whole disappointing. Neither from a purely scientific point of view, however, nor from a practical standpoint, was this material done justice to. I wish to lay particular stress on this point, because it shows at once the frequent value of work of a highly technical nature for practical purposes, even though it may be largely incomprehensible to any save an entomologist, and even to any save an advanced student of entomology. When Mr. Koebele's living specimens came to hand, I was fairly well acquainted with the published facts already known about these leaf-hopper parasites. This published information, however, was of the most meagre description, apparently only three or four of the great numbers of known species having been bred or having had their habits studied. Further, of those which had been bred, in most cases only a few individuals had been reared and information as to diversity or uniformity of habits was almost wanting. In one case only, one of these parasites had been recorded as attacking two species of leaf-hopper, and those so utterly different in all points of structure, as to lead one to suppose that the Dryinidae might be indiscriminate in their choice of host. I refer to the case of *Labeo typhlocybae* and *Dryinus ormenidis* discussed in this Bulletin on pp. 485 and 492. We now know that, in reality, these parasites generally are most particular as to their choice of host, and those which attack leaf-hoppers of the Delphacid group, to which our cane-hopper belongs, do not even extend their attacks to species outside this group, still less will they attack such different hoppers as are included in the great Jassid series. Now the living material sent to me by Koebele from North America included parasites of many small leaf-hoppers, belonging to most diverse groups, many of which would never have attacked our cane-hopper, as their structure plainly shows. It was not until I was in Australia and had leisure to examine Australian parasites with some care that I discovered the microscopic characters, which are always found in those species which attack leaf-hoppers of the Delphacid group, as opposed to those preying on Jassids. For want of this knowledge, Mr. Koebele's material from North America was, as I have said, not done full justice to from a practical point of view; much time being wasted on parasites that never would have attacked our cane leaf-hopper. Still at least two

species of imported North American Dryinidae did attack our cane pest, and were reared on these in captivity, and their offspring liberated in the cane-fields, but neither of these has as yet shown up at large.

That Mr. Koebele's North American material has not been done justice to from a purely scientific point of view is due to the fact that the practical end in view, namely, to establish the parasites, naturally outweighed the former. There are ten North American species described or referred to in Pt. I of this Bulletin, but the number really collected and sent by Mr. Koebele was unquestionably considerably larger. With the exception of one or two species sent in great numbers by him, no individuals were killed by me as specimens for study. Some were turned loose in cane-fields, infested with leaf-hopper, and some were placed in large cages on growing cane plants similarly affected. The preserved material therefore chiefly consists of specimens that died a natural death in these cages, and which happened to be found subsequently, together with a few examples that emerged and died on the way to the islands, and, again, of a few examples collected and mounted by Koebele himself in Ohio and California.

From another point of view Mr. Koebele's work in Ohio and California was of great value, for it was extensive enough to show what kind of natural enemies of leaf-hopper might be looked for in other countries. In fact it was these prior investigations in North America that led him at once to investigate the eggs of the cane leaf-hopper in Australia for internal parasites and to at once discover their presence on this investigation.

MISSION OF KOEBELE AND PERKINS TO AUSTRALIA.

We reached Sydney in May, the weather being cold and on our first arrival very wet, so that little entomological work was done there. Mr. Koebele, however, wished to visit some of the orange orchards in the vicinity, with which he had become well acquainted on some of his earlier missions. A number of species of living ladybirds were accordingly collected and shipped to Honolulu. Being too far south for cane, not much attention was paid to leaf-hoppers, but the presence of hymenopterous parasites was demonstrated by the discovery of Dryinid sacs on the larvae of common Jassids.

Early in June we arrived at Brisbane, and on the first cane that we saw, a few plants in the public gardens, we at once ob-

served the presence of the cane leaf-hopper. A short stay of about ten days gave ample proof of the existence in Australia of a considerable variety of Hymenopterous parasites of leaf-hoppers, of Dipterous parasites of the genus *Pipunculus*, and of Stylopid parasites of the genus *Elenchus*.

At Bundaberg, about twelve hours by rail north of Brisbane, we spent another ten days in June. Here is an extensive cane district with our leaf-hopper everywhere present, but never in numbers such as we are accustomed to in these islands. In fact we never saw the hoppers nearly as numerous as they are on our least affected plantations. From eggs collected here Mr. Koebele soon bred out specimens of the Mymarid parasites he had felt so confident of finding.

From our observations on the habits of the cane leaf-hopper in these islands, it seemed probable that in tropical Australia this species would be in its greatest numbers in the colder months, so after a brief stay in Bundaberg, we proceeded north to Cairns, which place we reached at the beginning of July. This plan seemed very expedient, for by retreating gradually towards the south, as the hot season advanced, we hoped to prolong the season during which natural enemies for the cane leaf-hopper could be obtained. It appeared likely that effective work could only be done at Cairns for a month or two, since without a reasonably large supply of hoppers, it was evident that the parasites could not be found in sufficient numbers for shipment. This indeed proved to be the case, and by the end of August, leaf-hoppers and their eggs had become so scarce in the cane-fields, that we came south again to Bundaberg. At Bundaberg we made a long stay on this occasion, regularly sending off consignments of parasites, until here too, owing partly to the season and partly to the harvesting of the crop, the locality became unprofitable. After a short stay in Brisbane, at the end of the year, I returned to Honolulu, while Mr. Koebele proceeded to Sydney, where his attention was largely given to collecting beneficial insects for pests other than leaf-hopper. On the return journey Mr. Koebele spent one month in Fiji, the enemies of the cane-hopper in those islands being mostly similar to those already found in Australia. A fine consignment of the Chalcid egg-parasite (*Ootetrastichus*) of leaf-hopper was most important, as it enabled us to establish that important species without any doubt.

MODE OF SENDING OVER PARASITES.

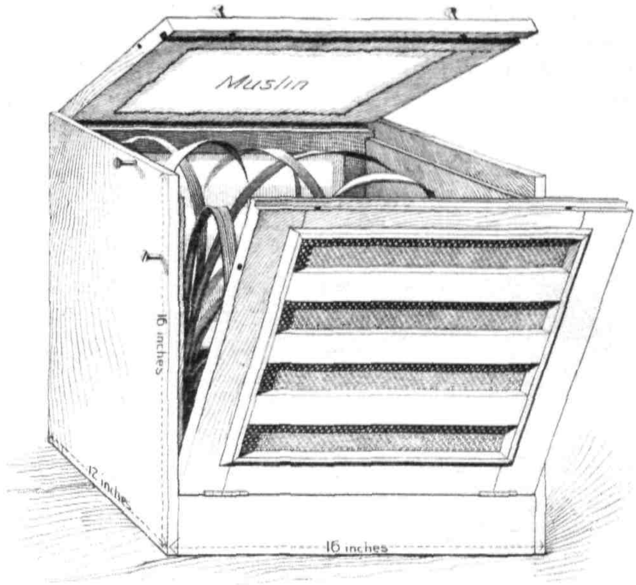
During the earlier part of our Australian trip all beneficial insects sent from Cairns were placed in cold storage. The fact that the coast steamers generally failed to make close connection with those leaving Brisbane or Sydney for Honolulu, and the necessity for reshipment and removal from the cool chamber, made it a matter of great difficulty to get any insects over alive. Of some predaceous species, however, such as certain ladybirds and some others, a small percentage of some species survived their long journey. These were packed in the way usually adopted by Mr. Koebele, in specially made wooden boxes nearly filled with slightly damped *Sphagnum* moss. The sides and bottoms are dove-tailed and hold well together in spite of the great dampness of the cool chamber. These boxes are made in three sizes, nesting within each other, the largest 4x3½x2½ inches, the smaller 3⅜x2⅜x2⅛ inches. When filled each is securely bound with strong string and the whole made up in one parcel for shipment, being wrapped in several sheets of stout packing paper.

With the very minute and delicate egg-parasites of the Eulophid and Mymarid families, which we were most anxious to get established in the islands, various methods were used. The cuttings of the midrib of cane-leaf containing eggs of leaf-hopper were made as short a time as possible before the steamer sailed. That they contained numerous parasites was certain from the samples we always retained to be sure on this point. Though these samples were always very small compared with the amount sent, yet we never failed to breed many parasites. Some of the cuttings were packed in the wooden boxes above described with moss, some in similar boxes with powdered charcoal, and some in tin boxes. It does not appear, however, that from the four consignments sent from Cairns, which must have included great numbers of parasitized eggs, that any of these parasites reached Honolulu alive.

Our subsequent consignments, from Bundaberg, were more successful, as was natural, the ports of departure of the Honolulu steamers being so much nearer. Cuttings of cane leaves containing leaf-hopper eggs sent from here produced both Eulophid and Mymarid parasites on arrival in Honolulu, and in fact some individuals of most of the Bundaberg species, that we desired to establish, reached the islands alive. Thus two of the Dryinid parasites of *Siphanta* (a *Paradryinus* and a *Neodryinus*)

were bred in numbers in Honolulu, and liberated for the purpose of attacking the introduced pest *Siphanta acuta*. Further, two of the small wingless species of the Dryinid family, belonging to the *Gonatopus* group, were likewise successfully imported, and one of these was successfully bred up in captivity on the cane leaf-hopper. A Proctotrupid parasite (*Aphanomerus pusillus*) that destroys the eggs of the *Siphanta* above mentioned, was also successfully imported, and is now well established at large in the islands and is already destroying a large percentage of the eggs of that leaf-hopper. All these were sent over from Bundaberg in cold-storage, the Dryinidae as larvae in the cocoon or pupae. Although eventually egg-parasites of the cane leaf-hopper were obtained from sections of leaf containing the eggs, sent in cold storage, yet it was, as has been shown, only after many attempts had proved unsuccessful. At one time it seemed as if the prolonged cold temperature of (supposedly) *from 40°-45° F. was fatal to every parasite, and so far as we know, it was so in the case of all those sent from Cairns, but not always to those from the less distant Bundaberg. This led me to suggest that we should have some special cages made, somewhat similar to those Mr. Koebele had previously employed in shipping stylopized leaf-hoppers from North America, in which living cane could be grown and the cages themselves sent on the open deck, allowing the delicate egg-parasites to emerge and reproduce in transit. For minute and delicate parasites, inhabitants only of tropical countries, there is very little doubt in my mind that this method of transportation surpasses all others. In fact the two first cages sent in this way, each stocked with a different species of Mymarid, both yielded parasites after their arrival in Honolulu. These cages were built very strongly and with considerable care, special precautions being taken by simple devices that everything fitted compactly and that light was entirely excluded at all joints and that escape of any insects would be impossible. The adjoining figure shows the construction. The top and front are both hinged, so as to be capable of being fully opened out; in the back and front are cut openings of 9 inches by 11; these openings being covered on the inside with fine strong white muslin fastened with shellac, and on the outside, as a protection, with a sheet of strongly perforated zinc, which itself is still further protected by transverse wooden bars. Although in such a cage the light is necessarily largely cut off, yet grass or cane plants will grow therein for weeks, though the leaves may become chlorotic. As a mat-

ter of fact, we chiefly used pieces of cane-stem planted in almost pure white sand, for these will root and the eyes sprout quite successfully under such conditions. A removable zinc tray fit-

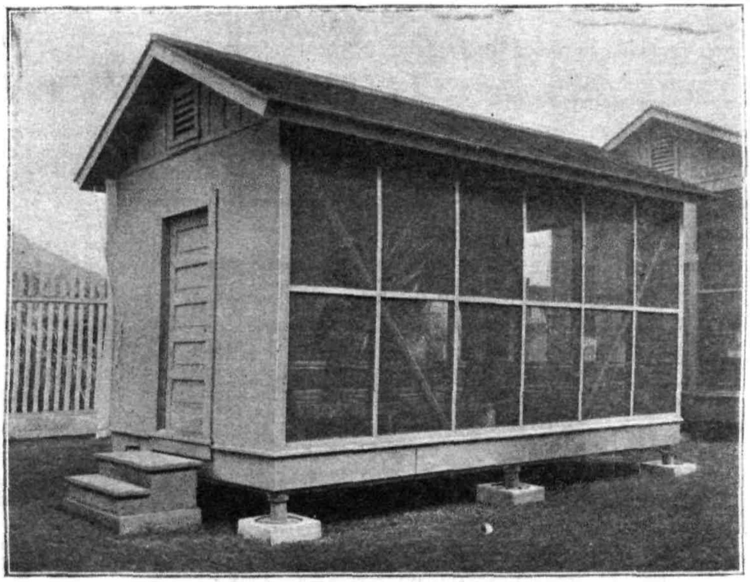


ting the bottom of the cage holds the sand or soil. For the journey this tray was securely fastened down by a couple of small nails.

HANDLING OF BENEFICIAL INSECTS AFTER ARRIVAL.

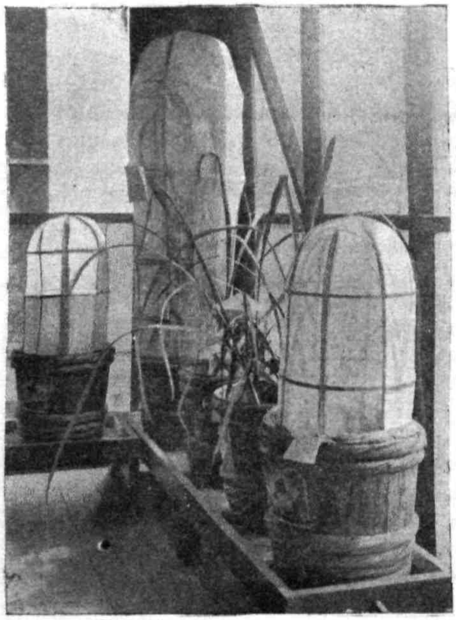
The successful handling of the various parasites and predaceous insects after their arrival was of course all important. The latter are generally of a much hardier nature than the former and any one at all accustomed to raising broods of insects can successfully propagate such creatures as ladybirds in captivity, provided that their proper food is procurable and climatic conditions permit. It is clear that for practical purposes the discovery of a parasite of an injurious insect counts for little (except for such scientific value as it may have) unless it can be

transported alive to the country where it is needed, and again the discovery and successful transportation alike count for nothing economically, unless it can be established at large after its arrival. *It is no doubt in many cases decidedly more easy to discover natural enemies of an insect pest than it is to establish them in a new and distant country.* We have heard some, who profess to be in favor of the repression of injurious insects by means of natural enemies, talk of the discovery of a parasite, as though the fact of this discovery were all important, whereas



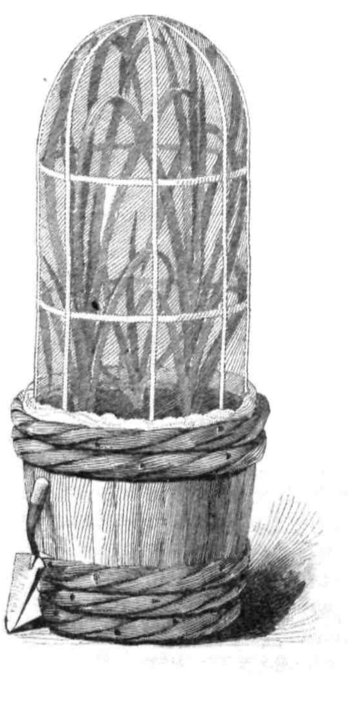
we must repeat that unless the parasite can be successfully introduced and established and duly performs its share of work in controlling the pest, the discovery is of insignificant importance. Further, cases where a single natural enemy is alone sufficient to keep down an injurious insect are rare and exceptional, and few pests are to be kept down in this way. As a rule, it is a complex of causes that keeps an insect in check, often the joint attack of various parasites and predators, and it may be various diseases and other conditions combined. Only in exceptional cases can the economic entomologist hope to succeed with a single parasite, as any practical field worker must

know. When beneficial insects, parasitic or predaceous, have been successfully imported, no methods by which they may be successfully established should be neglected. Predaceous insects are generally comparatively large and hardy, and can be safely liberated where their food is abundant. Parasites on the other hand are often excessively minute and delicate and may require the most careful handling. As a rule should some species that it is desirable to establish be received in any num-



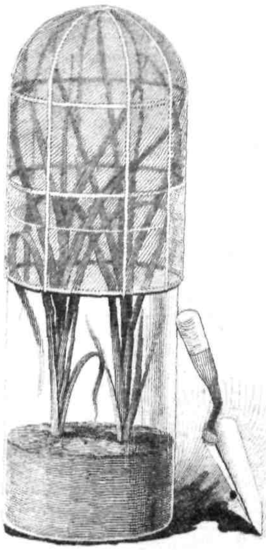
bers, it is always safer to divide them, and adopt various methods. It may be safely said that in nearly all cases (unless climatic conditions are altogether unfavorable) half the specimens received should be at once liberated in a suitable locality. Some minute Chalcids and other parasites are very easily bred in captivity, but this is by no means always the case. In rearing insects in captivity in tropical countries, there is one absolute essential, which is perfect isolation from ants and other carnivorous creatures. Several years ago, I had built for this purpose a small house isolated from the ground, the supports rest-

ing in water or water covered with a layer of kerosene oil. Similar houses are in use at our Experimental Station (see fig. of exterior, page viii, and on page ix one corner of interior with cages). It is necessary to take care that grass and weeds do not grow up so as to form a connection with the house; and, as will be noticed in the figure, the steps are built separately, and do not actually touch the house. The sides of these houses are covered with copper wire and in stormy weather blinds of thick white canvas can be let down for shelter from the rain, or on other days as a screen from excessive sun. The wire-mesh is fine enough to prevent the escape of a moderate-sized lady-bird. The earth used for plants in these houses is soaked in boiling water to kill ants and other injurious insects that may be present in any stage, and the wooden tubs, in which the plants are grown, are similarly treated. These tubs of Japanese make (manufactured as containers of the Japanese drink "saki") often afford hiding places to centipedes, cockroaches, ants and other most undesirable insects. On one occasion some years ago, in one night I lost a whole brood of about sixty individuals of a beneficial insect, that I wished to establish, from the attack of a small centipede accidentally carried into a house in a saki-tub, that had not been treated with boiling water. These saki tubs, as shown in the adjoining figure, are excellent for growing cane or other plants, which can be covered with a cap of fine muslin, fastened on a light bamboo-frame with shellac varnish. Either by a small door or a mere hole, which can be closed with a plug of cotton, the injurious insects and their parasites can readily be turned into such a cage and allowed to breed there.



In establishing the minute parasites that destroy the eggs of leafhoppers the following procedure was adopted. I will take the case of *Paranagrus optabilis*, whose life-history I have de-

tailed in Pt. VI of this Bulletin, as the same treatment was given to all the other minute parasites. Eight examples of the *Paranagrus* were bred from Queensland cage between January 17th and 30th. Four were liberated in the Experiment Station grounds, four were transferred to a glass-jar containing a young growing cane, in the leaves of which leaf-hopper eggs had previously been deposited. The jar used was a large glass battery-jar (the size is well shown in the adjoining figure by comparison with an ordinary garden trowel lying against it) containing very young cane plants. Round the jar near the top is bound a band of cotton or other material, on which rests the cap formed of muslin fastened over a fine bamboo framework with shellac.



These caps are remarkably convenient for handling delicate parasites. When one wishes to collect from the jar, by wrapping the whole in a black cloth and leaving only the top of the cap uncovered, after first dislodging the parasites from the plants by striking the jar with the bare hand, these will at once fly to the top of the muslin cap. The cap is then removed and laid on its side, the closed end or top being held towards the light, and the parasites can be collected in glass tubes with the utmost ease as they seek to escape at that end.

At the end of three weeks the first brood of parasites began to appear, and in all 47 individuals, all females, were obtained. Half of these were liberated, the rest being used to stock a number of new breeding jars similar to the one described. From these a very large number of individuals were reared, and these were treated in various ways.

Some were 'sleeved' out in the fields on growing cane much punctured with hopper. These muslin sleeves stretched on light bamboo framework are shown in the adjoining figures, the parasites being introduced through a small hole at the lower end, by means of a glass tube. A plug of cotton closes the hole, after they have been turned in; while in wet weather a cap of water-

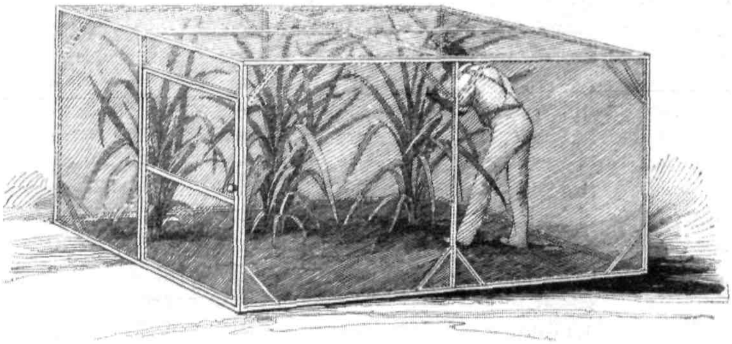
proof cloth can be fastened over the upper part of the sleeve to afford shelter.

In the breeding-houses large colonies were now raised on larger cane-plants in the saki tubs already mentioned; and other

still larger ones in the open field beneath light portable cages, which could be placed over several entire well-grown cane-plants, and were of sufficient size to allow one to enter and examine the condition of affairs within, and to make cuttings for further distribution. These large light cages were further

screened on the windward side by a strip of heavy white canvas, to break the force of the wind. All these methods were entirely successful, not only with the Mymarids, but also with the more sturdy egg-parasite of the genus *Ootetrastichus.*

While the parasites were still comparatively scarce and not easily obtainable in numbers for distribution, they were sent out in colonies, in the glass battery-jars already figured, to such plantations as stood in most immediate need. To the various plantation agents was left the choice, as to which of their plantations should be first supplied.



Subsequently as the cane in the experiment station became well stocked with parasites, it was only necessary to take cuttings of the midribs of cane leaves well filled with eggs and send them to the plantations in a very simple form of cage. Prior experiments had proved that from such leaves parasites would continue to emerge daily for at least two weeks after the cuttings were made. All that it was necessary for the recipient to do was to hang the cage in a suitable spot, the large number of parasites that would emerge from each cage making it almost impossible to fail in establishing them. The emergence of numbers of individuals day after day rendered the occurrence of unfavorable weather (which is so frequently a cause of failure in establishing beneficial insects, when liberated at one time as adults) a matter of small account.

EFFECT OF VARIOUS NATURAL ENEMIES IN CONTROLLING LEAF-HOPPER.

Having dealt with the introduction, propagation and distribution of the several parasites, we will now consider the practical effect of these and other natural enemies in diminishing the leaf-hopper pest. There are yet in Australia and Fiji, as can be seen by the student of the various Parts of this Bulletin, a number of other natural enemies of leaf-hoppers, which, introduced, would certainly attack our cane leaf-hopper, though either we did not attempt to introduce these, or were unsuccessful in the attempt. I have already, in my last annual Report to the Committee on the Experiment Station, stated what parasites we especially desired to import and the reasons for this, but for the sake of completeness, I here make some repetition. Thus in choosing what natural enemies it was desired to introduce, we had to consider: (1) their effectiveness or importance as destroyers of the pests; (2) the possibility of successful transportation; (3) the probability of their thriving in a new country; (4) the rapidity of their increase, when established. On the first two heads, there is nothing special to remark, but the third was a matter of great importance. When one considers the excessive difference in climate between many of the plantations, the extremes being shown by one where cane is grown on the windward side at an elevation of about 1500 or more feet, with its excessive rainfall, and one nearly at sea level on the dry leeward side, where cane can exist only by constant irrigation, it is obvious that comparatively few species of insects can be expected to thrive equally well under such diverse conditions. Consequently we had need primarily of parasites of wide-spread range in their own country, not such as were of local occurrence only.

The fourth consideration, that is the rate of increase, was to us of the greatest importance, since we had to deal with a pest already established for years, and that had no doubt reached its average numerical maximum throughout the islands. In this the little Mymarid egg-parasites of the genera *Anagrus* and *Paranagrus* excel. They complete their life cycle in about three weeks in these islands, and apparently breed at the same rate, or nearly so, at all seasons of the year. Further they are largely parthenogenetic, the male sex being only produced at rare intervals.

The Tetrastichine egg-parasite (*Ootetrastichus*) on the other hand is a comparatively slow breeder, taking fully twice as long as a Mymarid to complete its life-cycle or longer still. It however probably produces twice as many eggs as the other and is, so far as is known, entirely parthenogenetic, no male having ever been seen. If we judge the effectiveness of the two parasites merely on rate of increase (reckoning the life cycles as 20 and 40 days respectively), and suppose that the Mymarid produces 20, the Tetrastichine 40 female young, at the end of six months the latter will have produced four thousand and ninety-six million descendants, but the Mymarid in the same time will produce more by one million times. In reality no case is of this simple nature, the habits and constitution of the parasites have to be considered. Thus the Mymarid is much more delicate than the other, and liable to be decimated by storms, but it lays its eggs within a very short time of emergence, while in *Ootetrastichus* the period of egg-laying is extended over weeks. The latter, besides its robust nature, has this advantage, that each individual is bred at the expense of *the whole contents* of an egg-chamber of the leaf-hopper, while of the Mymarid each individual is bred at the expense of only a single egg.

If we consider the effectiveness of the four egg-parasites, *Paranagrus optabilis, P. perforator, Anagrus frequens,* and *Ootetrastichus beatus, in areas where all are well established*, we must rate the first-named as *at present* by far the most effective. As I have previously pointed out, this species is capable by itself of destroying about 50 per cent of the cane-hopper's eggs and *Anagrus frequens* and *P. perforator*, extraordinarily numerous as they appear, where seen alone, are but as isolated examples in the crowd, where all are well established in one spot. The *Ootetrastichus* slowly but steadily increases in numbers, and on many plantations I expect that it will ultimately be the most efficient of all parasites. I do not think that it can show its full value till 1908, for each harvesting of the cane crop is necessarily a very great setback to its natural increase. *Anagrus frequens*, under which name are probably more than one species, or at least one or two distinct races of a single species, although it appears at a disadvantage, when in company with *Paranagrus optabilis*, is nevertheless a most abundant parasite. In Part VI of this Bulletin I have compared the habits of the two and need not refer to the matter here, but I may say that as many as eighty or a hundred exit holes of the *Anagrus* have been counted in a single cane-leaf, so that its great utility is unquestion-

able. *P. perforator*, common in Fiji, attacking eggs of hopper laid in thick stems of grass, more rarely those in cane, will probably gradually wander away from the cane-fields to attack the eggs of native hoppers, that are laid in stems and twigs, as it now chiefly attacks the cane-hopper eggs when these are laid in the stems.

Nor must it be forgotten, what valuable aid these egg-parasites receive in the control of leaf-hopper from other insects parasitic and predaceous, native or introduced. In fact, had there existed previously no restraint to the multiplication of the pest, no one who has paid the least attention to such matters can doubt that it would some time since have become impossible to raise any crop of sugar-cane in the islands. The reason why these natural enemies have not alone got the upper hand of the hopper is due to various causes. In the first place, a number of the parasites such as the Dryinid *Echthrodelphax fairchildii* and the parasitic flies of the genus *Pipunculus* are of local occurrence, and in many places cannot (for climatic or other unknown reasons) maintain their existence. This was well shown by the behavior of the first-named, which was distributed in thousands by the entomologists and the Plantation managers themselves to all the districts in the islands, but in many places did not thrive. Such, too, is the case with the predaceous black earwig (*Chelisoches morio*) which, a natural immigrant to the islands and no doubt acclimatised centuries ago, is found on comparatively few plantations. Other natural enemies are themselves periodically decimated by parasites, as is the case with the introduced green cricket (*Xiphidium varipenne*), which has its own egg-parasite (*Paraphelinus*). Other enemies like the common lady-bird (*Coccinella repanda*) introduced by Koebele years ago for other purposes, prey on young leaf-hoppers, in default of more favorite food, and this valuable predator too is itself subject to parasitic attack by the common Braconid (*Centistes*). At present the whole number of parasites and predaceous insects that attack cane leaf-hopper to such an extent as to render their services worth noting is considerable, as the following summary shows.

The most valuable are the four egg-parasites, which there is every reason to hope will become still more effective with reasonable time, one (*Ootetrastichus*) having as yet had no chance to show its full effectiveness.

The two Pipunculus flies (*P. juvator and terryi*) are restricted to certain localities and are native species, which have trans-

ferred their attacks from native Delphacids to the cane leaf-hopper.

The ubiquitous lady-bird (*Coccinella repanda*) is valuable as a destroyer of leaf-hopper, though originally imported by Koebele to destroy Aphis. It is hoped that other lady-birds, especially *Verania strigula* (=*V. lineola* of Pt. VII) may become established and do good work, as in Australia and Fiji, whence they were imported.

The earwig *Chelisoches morio* is a local species, but no doubt useful where it exists in numbers.

The green cricket (*Xiphidium varipenne*) is very valuable, but is most unfortunately heavily attacked at certain seasons by an egg-parasite.

The Dryinid *Echthrodelphax fairchildii* is locally valuable. At certain seasons in suitable, but limited, localities, it destroys a considerable percentage of hoppers. Its services are underestimated, because for a large part of the year it lies as a dormant larva in the cocoon, and parasitized hoppers at such a time are naturally hardly to be found.

There are many other natural enemies of more or less importance, e. g. the various predaceous Hemiptera, and the several lace-wing flies (Chrysopinae).

In addition to these insect enemies, we must mention the two fungous diseases of hoppers (amounting locally and at certain seasons to epidemics) which, long previously known to kill the native leaf-hoppers, have become transferred to the introduced pest. We also found one or more fungous diseases attacking leaf-hopper eggs in Fiji and Australia in all localities. With material imported from these countries, I easily infected eggs of the cane leaf-hopper under cover, and subsequently established the fungus at large in the field. As it was most probable that parasitized and healthy hopper eggs would be affected alike by the disease, and consequently many of the egg-parasites would be destroyed, it became a subject of discussion whether we should attempt to establish the fungus or not. As, however, throughout Australia, the fungus and parasite both attacked the eggs, Mr. Koebele was of opinion that we should try and establish the same conditions here. Consequently with the first cages sent to the plantations the cane cuttings and the cane itself were well sprayed with water containing spores of the fungous disease, so that these would be certainly carried abroad by the emerging hoppers and parasites. I imagine there is no doubt as to this disease becoming established in all suitable localities.

The question that one will now ask is: Are these parasitic and predaceous enemies combined sufficient to prevent any further serious damage from leaf-hopper? Though a natural one, it is hardly yet a fair question. The leaf-hopper was in numbers sufficiently great as to be injurious in 1900, and spread and increased greatly since that time. The distribution of imported natural enemies began about a year ago. Some of the best of these have been distributed much more recently still. To serve fifty or more plantations, many of great acreage and occupying many miles of country, with introduced parasites, must naturally take considerable time. One of our most important parasites, if it thrives here as in Fiji, as I have already pointed out, is at present hardly to be reckoned with. It should be of decided value next year, of much more the year after. It is merely a question of natural increase, for that it thrives here at large as well as in captivity is already proven. When one considers the enormous monetary loss, considering the size of these islands, that has been occasioned by the leaf-hopper, I do not think one should cease to seek natural enemies against the pest, until it is absolutely proven a pest no longer, however strong one's hopes may be that the present enemies are sufficient to cope with it. I have been told on the best authority and by those most interested, that the loss to these islands caused by the cane leaf-hopper since its first noticeable appearance in 1900 to the present time may be reckoned at millions of dollars, and one is justified in taking every precaution, where so much is at stake.

ON THE NECESSITY OF FURTHER DISTRIBUTION OF PARASITES IN THE CANE-FIELDS.

Owing to the manner in which cane is cultivated in these islands, the entomologist working along the lines that have been adopted to control the leaf-hopper pest, meets with a serious obstacle such as is not encountered in dealing with insects injurious to our other vegetation. I refer here to the universal custom of burning off 'the trash' over great acreages, after the crop has been harvested. I have been told that on the Colonial Sugar Refining Company's estates in Australia no such burning off is allowed. If this is correct, it may help to account for the insignificant numbers of our cane-leaf hopper there, as well as of several other insects of the same group,

which are fortunately not known in our cane fields. As, however, burning of trash is an established fact here, it becomes necessary to see what steps can be taken to provide against this serious disadvantage. I will first show whereof this disadvantage consists. The parasitic enemies of the leaf-hopper are mostly delicate and minute creatures, not accustomed to take prolonged flights. Their wings serve well to bear them from plant to plant, but for further distribution they are dependent on air-currents. If when a field of cane is cut the wind blows towards another cane field, no doubt some or many parasites will reach it, but if otherwise, probably none will do so. In burning over a field it is quite certain that almost every parasite yet present will be destroyed, but the adult leaf-hoppers on the other hand are well able to take care of themselves. When as an experiment, a patch of about nine acres of cane, so heavily attacked by leaf-hopper as to be useless, was set on fire all around to destroy these, it was noticed that the adult hoppers rose from the cane in a cloud and spread to other fields; so this plan for destroying them was of no value. I have in an earlier publication shown how quickly the leaf-hoppers spread to new fields of very young cane, and with what regularity they distribute themselves over the young plants. It cannot be hoped that the parasites will (except under rare and fortuitous circumstances, such as constant favorable winds) spread themselves in like manner, and in the same time. Yet it is essential that the parasites should be on the spot when the leaf-hopper *begins to lay* in order to secure proper control. If the supply of laying hoppers at the beginning of the great breeding season is very small, it means that there is not time for the attack to become serious before that season is over. It is when the hopper is least abundant, that one wants to be assured that it is being attacked by all possible enemies. When a field is already seriously injured and swarming with hoppers, not much immediate help can be given for obvious reasons. It will be easier to prevent such a condition than to find a remedy. If one could provide that in each large area of cleared land, ready for planting, there should be in the middle a small patch of some variety of cane most susceptible to the attack of leaf-hoppers, that this cane should be kept well stocked with these, and with a variety of parasites and predaceous insects, and itself be of sufficient growth to afford good shelter to all these, the condition from an entomological standpoint would be ideal. This patch of cane, being already of suitable age and growth

and stocked as aforesaid, at the time the much younger cane of the rest of the field began to be infested with hoppers, would daily be distributing thousands of natural enemies, that should control these. Although such a plan or modification of it might be adopted on some plantations, on others (at least such as are under irrigation) it would either be difficult, or altogether impracticable. Only in the case of some fields of long ratoons would the matter be very simple, when a small area of the original ratoon growth in each field could be left uncut, and if well supplied with hoppers and their natural enemies would serve later on to stock the rest of the field. Unfortunately, owing to the fact that ratoons are (except in unusual cases) not severely attacked as compared with plant-cane, this matter becomes one of minor importance. Otherwise, in the majority of cases, owing to the clearing of large areas and the burning of trash, it is probable that new fields will have to be supplied by cages similar to those already used. Two things will be absolutely necessary: (1) that the new fields be well supplied with parasites; (2) that they be stocked immediately the hoppers enter them and commence laying. This plan, though less satisfactory than would be the other method, is nevertheless simple, and does not call for much expenditure of time, nor for skilled labour. The one thing necessary to be positively ascertained is that the spot whence the cuttings for distribution are taken is well supplied with *all* the kinds of parasites that it is desired to establish in new fields. It is now well known to us that *all* these destroyers are not yet established *in all parts* of all plantations, and therefore at present unless an entomologist previously test samples from the spot, whence distribution is to be made, it is quite likely that some of the most valuable parasites will not be taken to the new fields. If a sample be submitted to the entomologists, it can be passed as fit to supply all necessary parasites to new fields, or if not, cages of the deficient species can always be supplied from the cane in the grounds of the Experiment Station in Honolulu. As the parasites are continually spreading and increasing, such expert examination will at the most be necessary for a year or two; for it is perfectly certain that by that time all the species will be so general that it will be quite impossible to take any extensive sample of cane-leaves that bear eggs of leaf-hopper, which will not contain all. Such in fact is now the case in the cane at the Experiment Station. To sum up, the clearing of all cane from large acreages is a decided obstacle to the complete success of natural enemies

of leaf-hopper, and the burning of trash aggravates the difficulty. As an offset to these conditions new fields should be supplied artificially with natural enemies, and they should be supplied as soon as any leaf-hoppers enter them. Of course future observation may prove this distribution unnecessary, but for the present it should be adopted.

LIST OF PARASITES AND THEIR HOSTS.

Below are listed the parasites and hyperparasites treated of in detail in the various parts of this Bulletin. In many cases it is not possible at present to give the exact host of each parasite, even though the latter was bred. In the first place, of the great number of species of leaf-hoppers collected by us in Australia, only about half are yet described, and in the second, many of the parasites were obtained only from nymphs, which, in the present state of knowledge, even the special student of Homoptera will probably be at a loss to refer with certainty to their proper species. The name "Liburnia," often cited below as a host, must be regarded in a very wide sense, somewhat as in Edwards' "British Homoptera," where it includes a number of recognized European genera. Applied to the Australian forms in the list below, it is likewise a composite genus, the components of which do not however, at least as a rule, agree with those in the work just mentioned. In this list of hosts, the leaf-hoppers have mostly been determined by Mr. Kirkaldy, but for the reasons given, comparatively few are referred to specifically. Consequently it is not necessary, nor advisable, at present to make a second list, giving first place to the hosts, though I hope that this may be done, when the working out of the Homoptera is completed. In the case of the Dryinidae I have listed all the species dealt with in this Bulletin, since only seven of the 65 have not been bred, and attention is thus called to those species about which information is wanted.

HYMENOPTEROUS PARASITES.

FAM. DRYINIDAE.

Parasite	*Host.*
Pseudogonatopus	
kurandae	Liburnia sp. nymph and adult.
juncetorum	Liburnia and other Delphacids, nymphs and adults.

Parasite	*Host*
palustris	Various Delphacids allied to Liburnia, nymphs and adults.
saccharetorum	Perkinsiella saccharicida, nymph and adult.
dichromus	Liburnia spp. nymphs and adults.
americanus	Liburnia sp.
opacus	Liburnia sp. (near Chloriona).
stenocrani	Stenocranus dorsalis, nymph.
melanacrias	Delphacid near Stenocranus.
kiefferi	Vanua vitiensis probably.
perkinsi	Various Delphacids allied to Liburnia, nymphs.
Haplogonatopus	
apicalis	Liburnia and other Delphacids.
moestus	Hadeodelphax, nymph.
brevicornis	Liburnia sp. (near Chloriona).
americanus	Liburnia spp.
vitiensis	Delphacid near Stenocranus.
Paragonatopus	
nigricans	Liburnia or allied forms.
Gonatopus	
australiae	Deltocephalus and other Jassids, nymphs and adults.
koebelei	Athysanus sp.
Neogonatopus	
ombrodes	Deltocephalus sayi.
erythrodes	Deltocephalus?
obscurissimus	Deltocephalus?
pulcherrimus	Nephotettix plebeius adult.
dubiosus	Deltocephalus, Nephotettix and other Jassids.
brunnescens	Athysanus curtisii.
pallidiceps	Athysanus sp.
vitiensis	Euleimonios sp.; also from Deltocephalus nymph.
Epigonatopus	
solitarius	Not bred.
fallax	Not bred.
Pachygonatopus	
melanias	Euleimonios and Athysanus, adults.

Parasite	*Host*
Chalcogonatopus	
gigas	Tartessus syrtidis, nymph.
optabilis	Deltocephalus, nymph, and Nephotettix, adult.
decoratus	Phrynophyes.
pseudochromus	Phlepsius.
Echthrodelphax	
fairchildii	Perkinsiella saccharicida, Aloha ipomoeae, etc., nymphs.
nigricollis	Various small Delphacids, Hadeodelphax, forms allied to Liburnia, etc., nymphs.
bifasciatus	Liburnia and allied forms, nymphs.
Dryinus	
ormenidis	Ormenis pruinosa and septentrionalis, nymphs.
Neodryinus	
koebelei	Colgar peracutus nymph.
nelsoni	Colgar peracutus nymph.
raptor	Siphanta, Sephena, Aphanophantia, Privesa, Scolypopa, Massila, Gaetulia, nymphs.
Paradryinus	
koebelei	Colgar, Siphanta, Massila, Aphanophantia (?) nymphs.
venator	Privesa, Massila and Siphanta nymphs.
threnodes	Siphanta and Colgar, nymphs.
gigas	Not bred.
leptias	Hasta hastata, nymph.
varipes	Siphanta, nymph.
Chlorodryinus	
pallidus	Nymph of (probably) Siphanta.
pseudophanes	Not bred.
Thaumatodryinus	
koebelei	Young nymph of Siphanta.
Eukoebeleia	
mirabilis	Bruchomorpha, nymph, and both short and long-winged adult.

Parasite	*Host*
Neochelogynus	
typicus	Not bred.
nitidus	Eurinoscopus spp.
leiosomus	Eurinoscopus sp. nymph.
dimidiatus	Eurinoscopus sp. nymph.
nigricornis	Eutettix sp. nymph and adult.
destructor	Eurinoscopus, nymph and adult.
cognatus	Idiocerus or Macropsis? nymph.
parvulus	Euleimonios? adult.
coriaceus	Euleimonios adult.
pallidicornis	Deltocephalus? nymph.
ignotus	Not bred.
Prosanteon	
chelogynoides	Tartessus (?) nymph.
melanostigmus	Not bred.
Paranteon	
myrmecophilus	Ipo spp, nymphs and adults.

FAM. PLATYGASTERIDAE.

Aphanomerus	
bicolor	Eggs of Eurybrachyine Fulgorids.
niger	Eggs of Eurybrachyine Fulgorids.
rufescens	Eggs of Siphanta or allied genera.
pusillus	Eggs of Siphanta.

FAM. MYMARIDAE.

Ooctonus	
australensis	Eggs of Tettigonia (albida or parthaon).
Gonatocerus	
cingulatus	Eggs of Tettigonia albida.
Alaptus	
immaturus	Eggs of Psocid feeding on fungus growing on honeydew excreted by leafhoppers.
Polynema	
reduvioli	Eggs of Reduviolus blackburni.
Anagrus	
frequens	Eggs of Liburnia or allied Delphacids.
columbi	Eggs of Liburnia.
Paranagrus	
optabilis	Eggs of Perkinsiella saccharicida.
perforator	Eggs of various genera of Delphacids.

FAM. ENCYRTIDAE.

Parasite	*Host*
Meniscocephalus eximius	Eurinoscopus sp.
Fulgoridicida dichroma	Eggs of Eurybrachyine Fulgorid.
Neocladia howardi	Eurinoscopus sp., nymphs and adult.
Echthrodryinus destructor	Neodryinus, Paradryinus, etc., larvae.
Echthrobaccha injuriosa	Baccha siphanticida (puparium).
Ectopiognatha minor	Eggs of Siphanta.
major	Eggs of Platybrachys?
Echthrogonatopus exitiosus	Many species of the Gonatopus group of Dryinidae, larvae.
pachycephalus	One or more of the Gonatopus group of Dryinidae, larvae.
Helegonatopus pseudophanes	One or more of the Gonatopus group of Dryinidae, larvae.
Chalcerinys eximia	Neogonatopus and probably allied genera, larvae.
Saronotum australiae	Pseudogonatopus dichromus, larva.
americanum	Pseudogonatopus, larva.
Cheiloneurus swezeyi	Dryinus ormenidis, larva.
gonatopodis	Pseudogonatopus, Echthrodelphax, larvae.
chlorodryini	Chlorodryinus pallidus larva.
Anastatus pipunculi	Pipunculus cinerascens, also Paradryinus.

FAM. EULOPHIDAE.

Parasite	*Host*
Ootetrastichus beatus	Eggs of Perkinsiella saccharicida and vitiensis.
Paraphelinus xiphidii	Eggs of Xiphidium varipenne.

FAM. TRICHOGRAMMIDAE.

Pterygogramma acuminata	Eggs of Tartessus syrtidis.

COLEOPTEROUS PARASITES.

FAM. STYLOPIDAE.

Halictophagus	
schwarzii	Agallia (?) sp. adult.
americanus	Agallia 4-notata, adult.
australensis	Tettigonia parthaon; and a species, possibly the same, attacks T. albida and others; adults.
phaeodes	Hecalus immaculatus, adult.
stenodes	Paradorydium menalus, adult.
Megalechthrus tryoni	Platybrachys or allied forms, adult.
Elenchus tenuicornis	Liburnia various species, also various other Delphacid genera e.g. Hadeodelphax, nymphs and adults.
Deinelenchus australensis	Platybrachys or allied forms, adult.

N. B. In Australia stylopized examples of Phlepsius?, Eutettix, and nymphs of Deltocephalus were also found, bearing male puparia of the parasite.

DIPTEROUS PARASITES.

FAM. PIPUNCULIDAE.

Pipunculus	
cruciator	Hecalus immaculatus, mature and nymph, also Tartessus nymph.
eucalypti	Rhotidus sp. nymph.
erinys	Eurinoscopus nymph.

Parasite	*Host*
hylaeus	Eurinoscopus adult and nymph.
comitans	Athysanus.
cinerascens	Probably on Privesa, nymph; the puparia of the parasite being found commonly on trees affected by these hoppers.
beneficiens	Various common Jassids, adult and nymphal, Phrynophyes, Deltocephalus, Athysanus.
helluo	Colgar peracutus nymph also nymphs of Gaetulia chrysopoides.
koebelei	Thaumatoscopus and Vulturnus, nymph.
monas	Deltocephalus (?) nymph.
picrodes	Tartessus sp.
anthracias	Thamnotettix (?), adult.
xanthocnemis	Liburnia or allied form, adult.
synadelphus	Deltocephalus nymph.
pseudophanes	Hecalus immaculatus.
juvator	Aloha spp., Perkinsiella saccharicida.
oahuensis	Aloha ipomoeae.
terryi	Not bred, but in company with Perkinsiella, no doubt by transference from Aloha or some other native Delphacid.

FAM. SYRPHIDAE.

Baccha	
siphanticida	Preying on nymphs of Colgar, Siphanta, and Jamella.

LEPIDOPTEROUS PARASITES.

FAM. EPIPYROPIDAE.

Heteropsyche	
poecilochroma	Eurybrachyine Fulgorid.
melanochroma	Supposedly on many genera of Jassids and Fulgorids, but it is not certain that the moths were really all one species.

Parasite	*Host*
micromorpha	Thanatodictya hebe.
dyscrita	Aphanophantia cuscuticida.
stenomorpha	See remarks under H. melanochroma above.
Agamopsyche	
threnodes	Stenocranus, Perkinsiella, and other Delphacid genera, long and short-winged adults.
Palaeopsyche	
melanias	On a commonplace Agalliine (?) found on terminal shoots of a Terminalia. No examples of this hopper seem to have been kept apart.

SUMMARY OF CONTENTS OF THIS BULLETIN.

In Parts I and X of this Bulletin the Dryinidae are discussed, their habits and structures being detailed. It is specially shown that those forms which attack Jassids, while often superficially resembling others parasitic on Delphacids, always differ essentially in the structure of the chelae from the latter. Consequently the same species or rather the same genus does not attack both of these indiscriminately. The nature of the larval sac is explained, and a similar sac is shown to exist outside the group in an anomalous insect (possibly allied to *Embolemus*) parasitic on Orthoptera. It may be added that this is also the case with some European Belytidae, which also form larval sacs on small Jassids. The economic value of Dryinidae is discussed, and the effect of hyperparasites on their utility. Some species reproduce parthenogenetically, though males occur. Sixty-two new species and fifteen new genera are described; the majority being bred specimens.

Part II deals with the parasitic Lepidoptera of the Family Epipyropidae. Their habits are given and the remarkable form of the young larva is described. One species is parthenogenetic, and no male of this is known. Six new species are described in three new genera, all having been bred from larvae.

In Part III the Stylopidae are discussed, their habits, the effect of their attack on their hosts, the frequent occurrence of a parasitic fungus in connection with their attack, the structure

of larvae and adults, and their classification being detailed. Two new genera and a subgenus (*nom. praeocc.*) are described, and eight new species.

Part IV deals with the *Pipunculidae*; their habits, the form of the larvae and puparia, and the classification of the numerous species. Thirty-two new species are described; the full description of one species, however, is omitted and will be found in Pt. X. All belong to the genus *Pipunculus*, and half the whole number of species were bred.

In Part V, some predaceous enemies of leaf-hoppers are considered. The complete life-history of the earwig *Chelisoches morio*, is given, and a detailed account of the lacewing-fly, *Chrysopa microphya*, its eggs, larvae and pupa case. Two remarkable leaf-hopper-eating Syrphidae are described as new species of the genus *Baccha*.

Part VI gives an account of the Mymaridae, their habits (the life-history of *Paranagrus optabilis* being detailed) and their classification. In addition, some egg-parasites of the Proctotrupoid family Platygasteridae are dealt with. Parthenogenesis is shown to be usual in some Mymarids. Twelve new species and two new genera (one in each of the two families) are described, all being bred.

In Part VII a variety of predaceous enemies of leaf-hoppers is considered, the life-history and habits of the Locustid *Xiphidium varipenne*, being very fully given, as well as the variation in length of the tegmina. The life-histories and habits of the Coccinellidae, *Callineda testudinaria*, *Coccinella repanda*, *Verania frenata* and *V. strigula* (under the name *V. lineola*) are detailed; also those of the Hemiptera *Zelus peregrinus*, *Reduviolus blackburni*, *Triphleps persequens* and *Physopleurella mundulus*, wholly or in part. *Xiphidium varipenne* is described as a new species.

Part VIII deals with Chalcids of the families Encyrtidae, Eulophidae and Trichogrammidae, and contains remarks on habits, classification and parthenogenesis. Thirteen new genera and nineteen new species are described, all bred, some being direct, others secondary parasites.

Part IX is devoted to leaf-hoppers themselves; their habits, and what is known of their life-histories is referred to or described. The life-history of the sugar-cane leaf-hopper is given in detail, and the various stages are described. The varying condition of the flight-organs of leaf-hoppers is discussed at length. Their systematic position and classification is very fully dealt with, a survey of previous systems being given, and a criti-

cism of these systems follows. The external structure of Homoptera is discussed at length, particular attention being paid to neuration, a synonomy of the varied terms used by different authors being given. Two hundred and thirteen new species are described, and eighty-four new genera.

Part X is supplementary to Pt. I and IV, and gives figures of structures, etc., discussed in Part I, which is without plates.

CONCLUDING REMARKS.

In the early part of this Bulletin I have referred to Mr. Koebele's work in North America in the summer of 1903. As I have pointed out, he was successful in finding there at least two species of parasites, which readily attacked the cane leaf-hopper in our cages, and broods were raised on these, and liberated in numbers in the cane fields. One of these was the species described by me as *Haplogonatopus americanus*; the other was raised in smaller numbers and none were preserved, but it was almost certainly a *Pseudogonatopus*. A great deal of time was spent in a vain endeavour to establish the Stylopid, *Elenchus*, which would most likely have proved a useful parasite, and we are now again trying by every means to introduce it from Fiji, where it attacks the Vitian cane-hopper. As to the Dryinids above mentioned, I have hopes that they may yet prove to be established, for it cannot be expected that they would increase at nearly so rapid a rate as the Mymarid egg-parasites. During the past fifteen years I have paid great attention to the rate of increase of insects imported into these islands, and collected statistics on this subject. I find that even with very prolific insects, of which several or many individuals have been introduced, it is rarely that they can be found by an entomologist for at least three years. I am now of course speaking of insects accidentally imported with plants, not those beneficial ones, which are specially reared under cover for economic purposes and distributed again and again in large numbers to many localities. I will take as an instance the Locustid, *Xiphidium varipenne*, because it is a species specially considered in this Bulletin, although it is not one of the several species, of which I know the exact date of importation. In November, 1892, a hard day's work produced two specimens of this cricket in the lower part of the Pauoa Valley; in 1893 and 1894 it was not seen. In 1895 I revisited the exact locality mentioned, and found a good many young crickets and a few old ones. In 1896 it had

extended its range down into the gardens in Honolulu, but was still far from numerous. By 1900, however, it had spread all over Oahu and also reached parts of the other islands, and in many places was in incredible numbers. That is to say, a hardy and prolific insect introduced probably some years previously to 1892 took at least five years to spread over a limited area, and to become at all noticeable, but having reached this point, in the next three years it increased to such excessive numbers, that it attracted the attention of many who pay little attention to such matters, owing to the fact of its frequently swarming round the lights in houses. I have digressed to this extent to show how impossible it is to secure immediate results with *every* kind of imported beneficial insect, and also how important it is in choosing one's species to consider which can most quickly produce visible results.

From Australia and Fiji the following egg-parasites were imported: *Anagrus* (two species, or two races of one species), *Paranagrus optabilis* and *P. perforator* (the latter possibly including two species or races), *Ootetrastichus beatus*. The two lady-birds (constant inhabitants of cane-fields in Australia) *Verania strigula* and *V. frenata* were raised in large numbers and widely distributed over the islands; so too was *Callineda testudinaria*, a ready devourer of leaf-hopper in captivity, but which, I fear, will forsake the cane-fields for forest trees. *Pseudogonatopus dichromus* though not yet established, no doubt could be, since it was bred on the cane leaf-hopper in captivity. Enemies of leaf-hopper that might have been established with good results but which failed (not, I think, because they could not under any circumstances be established, but merely from mischance) were the parasitic moth *Agamopsyche*, a specific enemy of the cane leaf-hopper, the predaceous Syrphid fly *Baccha*, and some other predaceous insects, which may after all prove to be established, the time since their liberation in my opinion being too short to allow of any certainty on this point.

Although the prime object of the six months mission to Australia, undertaken by Koebele and myself, was the study of leaf-hoppers and their natural enemies, yet it must be remembered that while we were together a great deal of our time was given to various entomological studies, both to other insects injurious to cane and their natural enemies, and also to insects injurious to other vegetation. After my return to Honolulu, Mr. Koebele, I believe, turned his attention still more to pests other than leaf-hopper. Throughout the period of our Australian mission

large numbers of beneficial insects not mentioned at all in this Bulletin, were collected and sent to Honolulu for the benefit of general agriculture. To publish details of all this work in full would require much time and space, and in fact a Bulletin as large or larger than the present one. We already know that some of these beneficial insects, parasitic and predaceous, are successfully established, although as yet very little special investigation of the matter has been made. I think that the introduction of almost any one of the species, that we know to have become established, would fully justify our mission.

There remains the pleasant task of thanking all those who have assisted us in our endeavour to control one of the worst insect pests these islands have yet seen. Our thanks are chiefly due to the Agents and Managers of Plantations in these islands, who have done everything possible to help us and taken much interest in our work. Especial thanks are due to Messrs. Wm. G. Irwin & Co., Ltd., and Theo. H. Davies & Co., Ltd. who by their kind offices, as representatives of the steamship lines between Honolulu and the Australian Colonies, and by letters to the officials of other steamship companies in Australia and Fiji, did much to secure for us a careful and successful transportation of the living insects. To Dr. Kottman, of the Colonial Sugar Refining Co., who on previous missions also has aided Mr. Koebele, we were indebted for letters to the Managers or owners of many sugar estates throughout Queensland and in New South Wales, and we regret that from pressure of work we were able to visit so few of these. Mr. Alexander Craw, Superintendent of Entomology under the Board of Commissioners of Agriculture and Forestry of this Territory, has given us his assistance in the handling of the beneficial insects imported, a work in which he has had a very great experience. He also, previously, as Horticultural Quarantine officer and Deputy Commissioner of the State of California, took charge of and forwarded to us the living insects despatched from Ohio by Mr. Koebele in 1903, and assisted us in like manner on former occasions. Without his expert handling, it is probable that many of these insects would have died while awaiting shipment to Honolulu. To many others, whom it is impossible to name severally, we are indebted for aid rendered, both in Australia and the United States.